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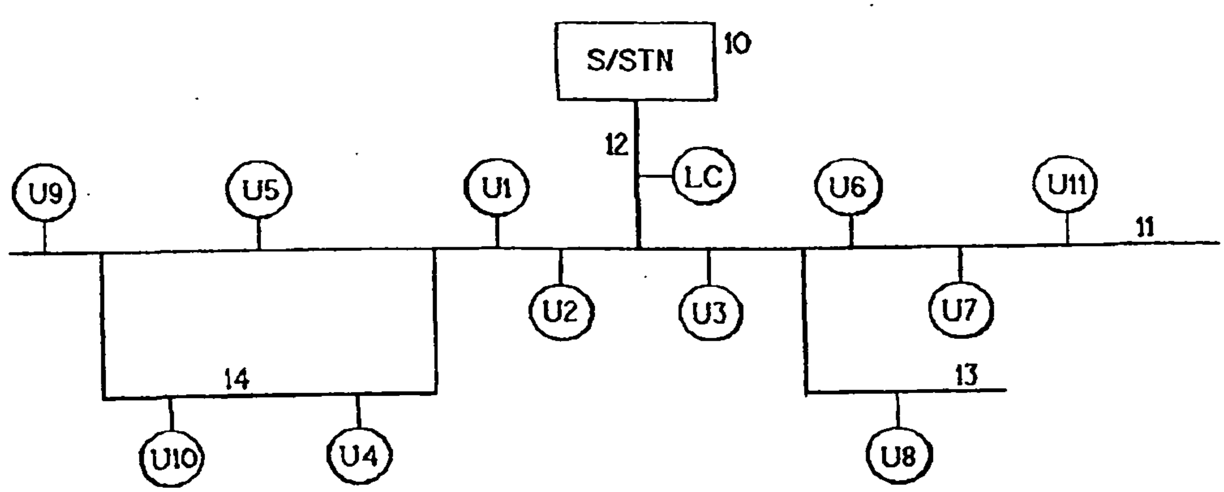

(57) Abstract

A remote mains meter reading system comprises a mains system (10, 11, 13, 14), a central station (LC), and a plurality of meters (U1-U11) communicating with the central station by means of messages passed over the mains system. All of the meters act also as message forwarding (relay) units, but knowledge of the topology of the system (i.e. which meters can communicate with which) is known only to the central station. All messages are sent out by, and return to, the central station, the message format includes a list of meters through which the message is to pass. The central station can send out a variety of enquiry (SEARCH) messages to determine the system topology, assign labels to meters, etc. If the mains system includes link boxes coupling different areas together, these boxes preferably filter out messages and includes link units which controllably couple the different areas together.

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Mains Signalling Systems

The present invention relates primarily to mains signalling systems, though it is also applicable to other systems having similar characteristics.

Contents

Introduction

Mains signalling - general

In most major countries, electricity is supplied on a wide scale by electricity generating and distribution companies (electricity utilities). The distribution network normally consists of a large number of consumer voltage networks to which domestic and small business consumers are connected, with the consumer voltage networks being supplied through an intermediate and high voltage distribution system. The distribution network, or various portions of it, is commonly termed the grid or the mains (the term "grid" is more commonly used

for the intermediate and high voltage portions, the term "mains" for the final consumer voltage portions). We will use the term "low voltage" for the consumer voltage networks, which may for example operate at 110 V or 230 V, or 440 V 3-phase. (These voltages are of course high compared to the internal voltages typically 3.3 V or 5 V, at which most electronic equipment operates.)

The use of the mains for signalling has often been proposed. Systems are available for intercommunication between rooms in domestic premises (typically for "baby alarms"), for coupling to the telephone system, and for transmission of data between computer units. Many proposals have also been made for the use of mains signalling for remote meter reading (primarily for electricity meters, though gas and other meters can in principle be coupled to the mains for this purpose, preferably through electricity meters). Such signalling is termed mains, mainsborne, or power line carrier (PLC) signalling.

There is in fact an international standard now for such signalling, using frequencies in the general region of 3 - 150 kHz. (The standard is CENELEC EN50065.1, which specifies that frequencies in the band 3 - 148.5 kHz are available for signalling on low voltage electrical installations. This bandwidth is divided into several smaller bands with various uses and permissions associated with them; for example, the 9 - 95 kHz band is reserved for electricity suppliers and their licencees.)

Mains signalling - metering

The signalling which is performed by the electricity suppliers is likely to be largely concerned with metering and more generally with load and system control. This will therefore largely operate over the low voltage portions of the mains. There will be a central station or controller, which can conveniently be located at a distribution transformer from the intermediate or high voltage grid to the low voltage mains, and this central station will communicate over the (low voltage) mains with the meters of the various premises (largely household or domestic and small commercial) on the mains.

The central station will normally collect information from the meters with which it communicates and be coupled with some higher level control means such as a master station which is coupled to several such central stations. This coupling may be over some independent transmission medium such as the tele-

phone system, but may use the mains or grid system. These higher level communications must of course be independent of the communication between the central station and the consumer meters. This can be achieved by using different frequency bands or by using the intermediate and high voltage grid systems therefor, since such signals do not normally pass through power transformers effectively.

In principle, however, the area served by a single central station may extend beyond the low voltage mains coupled directly thereto, through parts of the intermediate or high voltage grid into further distinct low voltage areas. This can be achieved by providing means for coupling the signals round the power transformers if necessary.

Mains signalling - problems

There are however two major problems with mains signalling. One is that the mains tend to be noisy, as a result of loads being switched on and off and from the inherent characteristics of certain types of loads. The other major problem is that there is significant dissipation or attenuation at the preferred signal frequencies; further, the attenuation is dependent on the particular operating conditions of the mains system, and varies according for example to the loading of the system.

Remote meter reading has therefore not achieved significant practical implementation, and a significant reason for this is the limited distances over which signalling can be accomplished reliably.

The noise problem can generally be overcome by a variety of known techniques, such as error detection and correction techniques, requiring acknowledgement of reception, and repetition of lost messages.

The attenuation problem is to some extent related to the noise problem, since the effect of low level noise will increase as the signal level falls. Thus good techniques for overcoming noise will to some extent compensate for signal attenuation. However, the signal level will eventually fall below the level at which it can be reliably detected even in the absence of significant noise. Some further technique for overcoming the attenuation problem is therefore required.

A standard technique for overcoming attenuation problems in transmission systems generally is to provide suitably located relay stations. In the context of mains signalling, however, this technique has various problems. The inclusion of relay stations in the system increases the complexity and expense of the system, and the installation of the relays can present considerable difficulties. Further, a considerable number of relay stations will generally be required, because it is necessary to locate them to cope with the "worst case" situations in all parts of the system, ie where the attenuation is at the maximum which can reasonably be anticipated throughout the system. (There may for example be potential "dead spots", due eg to signal reflections, close to the signal source while communication to more distant locations is still reasonably reliable.) Yet another complication is caused by the fact that the mains system itself may be extended or modified over time.

As an alternative to using relay stations, proposals have been made for the use of certain of the end units themselves to perform the function of relays.

US 4 230 989 (Buehrle/Engineered Systems) is concerned with a radio communication system in which a remote station may be unable to communicate directly with the central station. To overcome this, the central station communicates with the remote station via a further remote station termed a partner station. The partner station is programmed to transmit and receive messages for the remote station (as well as for itself, of course). The remote station is assigned a new address, and the partner station changes the address in messages for the remote station from its original address to the new address in messages going from the central station and the other way round in messages going to the central station.

EP 0 201 253 A (Trask & Wiener/EMI) shows a mains signalling system in which certain of the meters are also used as relays. If the central station finds that it cannot reach a distant meter directly, it sends the message instead to a relay meter, and that relay meter then sends the message to to distant meter. If one of these sub-links also fails, eg that between the central station and the relay meter, the central station may then try to send the message to a second, closer relay meter which in turn tries to send it to the (first) relay meter, and so on.

The present invention

We have realized that these problems can be overcome by providing substantially all meters with a repeater function. According to this aspect of the invention, therefore, there is provided a remote mains meter reading system comprising a mains system, a central station, and a plurality of meters communicating with the central station by means of messages passed over the mains system, in which substantially all of the meters act also as message forwarding (relay) units.

Thus substantially all of the relay units also incorporate metering (end unit) functions; similarly, substantially all of the meters also incorporate relay unit functions. Thus both relays and meters can simply be termed units (as can also the central station).

It will be realized that the meters may, in addition to being read, also be controlled to some extent by the central station (eg to set tariff rates). Further, the meters may be used for other messaging functions, eg reading gas and water meters (suitably coupled through the electricity meters), alarm signalling systems etc.

Each meter contains message receiving circuitry and message transmitting circuitry. Each meter also listens continuously for messages, and must accept any message which it hears to determine whether or not the message is directed to that meter. Where appropriate, we shall distinguish messages which reach a meter by describing the meter as "hearing" any message which reaches it, but "receiving" the message only if the message is directed to that meter.

For the meter to act as a repeater or relay, therefore, no significant additional circuitry is required in the meter. All that is required in a slight amount of additional processing, for the meter to determine whether it is to act as a relay unit and, if so, to retransmit a message which it has received.

The topology of the communication system will normally be branched. That is, the central station will normally communicate directly with several meters, each of those will normally communicate with several further meters, and so on. (The topology of the communication system is somewhat abstract, and must be distinguished from the physical topology of the mains system which supports the com-

munication system. We will normally be concerned with the former, and will use the term "topology" alone for the former.)

In systems of the present type, there is a danger of collision between messages; that is, a unit hearing (or receiving) two messages simultaneously, with the messages interfering with each other and both thus being garbled. In some circumstances, collisions can be avoided, eg by the central station waiting for a reply to a message which it sends out before sending another message out. However, in general the possibility of collisions cannot be avoided in the present system. Techniques for dealing with collisions are well established, eg in local area networks in computer systems, and can therefore be employed as appropriate in the present system; the technique known as p-persistent CSMA (carrier sense multiple access) will normally be a suitable one.

Message routing

A major feature of the present system is that the message routing - ie the determination of the routes which messages take through the network - is determined substantially entirely by the central station. This is achieved by the central station including, in each message, a list of the meters through which the message is to pass.

In the present system, the only station with any significant knowledge of the topology of the system is the central station. (This is in contrast to the system of EP 0 201 253 A (Trask & Wiener/EMI) noted above, in which the meters acting as relays contain routing information which they use for forwarding messages which they are required to relay.) Message routing is therefore controlled exclusively by the central station. A meter cannot send a message of its own volition to the central station, because it does not know how to reach the central station.

To read a meter, the central station sends out a message to the meter, which inserts its reading into the message and sends it back to the central station. With some messages from the central station (eg to set the meter clock, change a tariff rate, etc), the return of the message is not essential. However, it is highly desirable for all messages to be returned, as a confirmation to the central station that they have been received.

The simplest form of message routing management is for the meter list to remain in a message permanently, from its initial sending out by the central station to its return to the central station. However, as the message returns to the central station, each meter can obviously be dropped from the list as the message passes through that meter. More radically, meters can be deleted from the list on the outward journey of the message if, for each meter the message passes through, its identity is retained by the next meter. Each meter through which the message passes will then retain a minimal amount of routing information - the identity of the next meter on the route back to the central station.

Topology monitoring

A feature of the present system is that it can readily be made adaptive to changes of topology. This is particularly important for mains meter reading. The transmission characteristics of the mains supply system are liable to change (over time periods of the order of minutes to hours). Also, there will be occasional changes in the number and locations of the meters of the system. Both these types of changes will change the topology of the system.

To monitor the topology, the central station sends out search messages which request identification from meters receiving them - which, in informal terms, ask "Is anybody there?". (For this, any message heard by a meter is necessarily also received by it.) Each such message is sent through a chain of known meters, the last of which (the end-of-chain meter) broadcasts the request for identification. (The central station itself can be regarded as the end-of-chain unit for the initial stage of topology monitoring.)

Any meter receiving the identification request responds with its identification, and the end-of-chain meter returns a reply to the central station including that identification. Usually, there will be several responses to a request for identification. Obviously, only meters which can achieve bidirectional communication with the end-of-chain meter will be identified.

The central station can therefore gradually construct a map of the system. It first transmits a request for identification, and records those meters which respond, as being 1 step away from itself. It then sends, to each of those meters in turn, a message setting up that meter as an end-of-chain meter and so constructing a list of meters which are 2 steps away from itself. The process

is repeated until all meters in the system have been recorded. The topology of the system can thus be determined.

The topology of the system can then be continuously maintained as a background process, so that changes in the topology (ie meters losing communication with each other or communication between meters becoming possible) can be tracked.

Meter identification

We have assumed so far that each meter has a single distinctive address, which is used for all purposes (specifically, for identifying it and addressing it). It is however preferable for each meter to have a unique identifier (which may be assigned to it during manufacture), and also to be assigned a distinctive label by the central station (with the labels being distinct from the identifiers). In practice, the labels can be usually considerably shorter than the identifiers, so that messages are shortened.

The use of identifiers and labels allows two modes of operation, which we will term general and restricted.

In the general mode, when the central station sends out a request for identification, a meter receiving the request returns its label if it has one and its identifier if not. The central station can thus immediately distinguish those meters which it has already established communication with from meters which it has not yet established communication with. When the central station receives an identifier, it returns a message to the relevant meter assigning it a label.

The restricted mode of operation is for only unlabelled meters to respond to requests for identification. This mode of operation is somewhat simpler than the general mode. The general mode is capable of generating a full topological map, including redundancies, while the restricted mode generates a minimal spanning tree.

We have assumed so far that there is a single central station. In a large grid system with many consumers, the use of a single central station can lead to unduly long signal paths (ie paths with high hop counts) and to message congestion, and makes the system unduly reliant on the integrity of the grid and the

central station. It is therefore often desirable to have a plurality of central stations.

If each meter has a single distinctive address, then each central station can potentially reach the entire network. The network can be partitioned between central stations by the somewhat crude technique of limiting the signal path lengths. This will usually result in many meters being in communication with more than one central station. The information by each central station must then be compared with that gathered by the central stations, so that duplicated copies of information from a single meter gathered by the second central station can be deleted.

The use of identifiers and labels allows this problem to be overcome. The labels are chosen so that each central station has a unique set of labels for assignment to its meters. If one central station, after sending out a request for identification, receives in response a label assigned by another central station, it can ignore that response.

This system can be slightly modified and expanded by allowing the central station to keep a record of the meter as belonging to another central station. The central station can then, for example, use that meter as a relay unit, but not as an end unit.

The system can be further modified and extended by including, in the labels, a distance (hop count). If a central station finds that it is much closer to a meter than the central station which has given that meter a label, it can relabel that meter with a label of its own. (It may also be possible for central stations to exchange information and so rationalize the partitioning of the meters.)

Specific Embodiments

A communication system embodying the invention and variants thereof will now be described, by way of example, with reference to the drawings, in which:

Fig. 1 shows a mains power distribution and metering system;

Fig. 2 shows the topology of the Fig. 1 system;

Fig. 3 is a block diagram of a meter of the Fig. 1 system; and

Fig. 4 is a block diagram of the central station of the Fig. 1 system.

Mains system and system topology

Fig. 1 shows a mains system powered from a substation 10. The system comprises a main branch 11 connected to the substation 10 via a line 12, a second branch 13, and a loop branch 14. A central station (local controller) LC is connected to the system adjacent to the substation 10, and various user consumption meters U1-U11 are connected throughout the system as shown. (It will often be convenient for the local controller to be located at the substation, but this is not essential.) All the meters can also act as relay units.

The mains system is shown in highly simplified form; in practice, it will typically extent over an area of the order of 1 km in diameter, and the number of meters will typically be in the region of 100 to 1000.

Fig. 2 shows a typical topology for this system. The local controller LC can communicate with meters U1-U3; meter U1 can communicate onwards with meters U4 and U5; and so on. This tree corresponds roughly with the physical closeness of the meters in the physical network of Fig. 1, but the correspondence will in general not be exact.

Communication in this system is essentially through and controlled by the local controller; this is the master, with all the meters being slaves. Broadly, each meter accumulates information regarding the electricity consumption which it measures, and the local controller gathers this information from the meters. The local controller can also control the meters, eg by changing their tariff rates. Any convenient message encryption and/or authentication scheme can be used if desired; for example, each meter can have suitable keys for these purposes.

In a typical system, the maximum path length, ie the maximum number of hops required for the local controller to reach a meter, will be 3 or 4. In some systems, however, the number of hops required to reach the most remote meter may be considerably greater than that.

Message format and transmission

To read the contents of a meter or to control it, the local controller sends out a message to the meter, and the meter returns the message suitably modified. (In principle, if the message is a pure control message the meter need not return it; but in practice, it is desirable for the meter to return such a message as an acknowledgement and confirmation that the message has been received.)

The message format comprises three main fields: a command field, a route field, and a data field. (Obviously the details of the message format may be varied slightly. For example, each message may be given a serial number, so that the local controller will be able to distinguish between different messages returning from the same meter.)

The command (or instruction) field defines the action which the meter is to take: eg return a reading, or change a tariff setting.

The data field is used primarily for the data involved (eg a meter reading being returned, or a new tariff setting), but can also be used as an extension to the command field (eg to indicate which of various possible readings is to be returned); in some instances, the data field may be empty or absent.

The route field defines the path which the message is to take through the system from the local controller to the meter and back again, and comprises a control subfield and a label sequence - a sequence of meter labels defining that path. The control subfield includes a direction indicator (eg O for outbound and I for inbound, which can be coded as a single bit), a label sequence length, and a marker which is effectively moved along the label sequence as the message moves through the system to indicate the next meter which is to receive it. The marker may consist of a pointer in the control subfield. We will term the label indicated by the marker the active label. This marker is moved along the label sequence as the message passes through the system.

Thus for a message being sent to meter U7, for example, the data path field will initially consist of a control subfield O-3-2 and a label sequence LC-U3-U7. In the control subfield, the first character, O, indicates that the message is an outbound one, the second is the label sequence length, and the third is the pointer. When the message is first sent out by the local controller, the pointer

indicates meter U3. This message reaches meters U1 to U3 (and possibly other meters as well). Each meter which hears the message looks at the active label, and ignores (discards) the message if that label is not the meter's label. Thus meter U1 will hear the message, but will discard it because the active label (U3) is not the label of that meter. Meter U2 will similarly hear the message but discard it.

Meter U3 hears and receives the message, as the label of this meter matches the active label. Meter U3 therefore increments the pointer to point to the next label in the label sequence, ie to U7, so that the control subfield is now 0-3-3. Meter U3 then sends the message out. Again, several units (the local controll LC, meters U6, U7, and U8, and possibly other meters as well) will hear the message. Of these units, all except meter U7 will discard the message as their labels do not match the active label (U7) in the message.

Meter U7 will hear and receive the message, recognizing that it is the intended recipient as its label will match the active label. The active label is now the final label in the label sequence, so the message has now reached its final destination, as indicated by the fact that the label sequence length and the pointer are now equal. Meter U7 will therefore carry out whatever operation is specified by the command field of the message; eg loading a reading into the data field of the message. This meter will also change the direction indicator to 1, and decrease the marker to point to the next label back along the label sequence (ie to point to U3),so that the control subfield is now 1-3-2. It will then sei the message out.

As before, the message is likely to be heard by various units, of which all but meter U3 will discard it. Meter U3 will receive it, decrement the pointer to point to the next label back along the label sequence (so that the control subfield is now 1-3-1), and send the message out. Again, the message is likely to be heard by various units, of which all but the local controller LC will discard it. The local controller will recognize that the active label matches its own label, and will therefore receive and process the message appropriately.

This message transmission system can in principle be extended relatively easily to allow different outward and return paths. However, to utilize that effectively, topology information would have to be gathered separately for vari-

ous potential the outward and return hops between units, and that information would be extremely difficult to gather effectively.

As described so far, the full label sequence is maintained in the message throughout its travel from the local processor to the final destination and back again to the local controller. The system can however be modified to allow the label sequence to contract as the message passes through the system.

The labels for the meters through which the message has already passed on its return path to the central processor are clearly superfluous. Thus for a message in its return path, each meter can delete its label from the message (though it may be convenient to retain the label of the final destination in the message.) The pointer is then not required either in the returning message. This technique has a significant advantage in reducing the average message length.

Preferably, however, a more substantial modification is made to the basic message transmission system. In this modification, the labels in a message are deleted one by one on the **outward** journey of the message. To enable a return path for the message to be found, each meter strips off, from the label sequence, the label of the **preceding** meter in the sequence, and retains that label in a return label register. On the return journey of the message, each meter forwards it to the unit whose label it has retained in its return label register. This technique further reduces the average message length.

Thus for a label sequence of say LC-U3-U7-U15, meter U3 receives the message from the local controller LC; this meter U3 strips off and retains the preceding label, LC, and transmits the message with the shortened label sequence U3-U7-U15. Meter U7 receives the message, strips off and retains the label U3, and forwards the message with the shortened label sequence U7-U15. The final unit, meter U15, receives the message, takes whatever action is required, and returns the message with the label U7. When meter U7 receives the message, it looks up its stored label (U3) and sends the message to meter U3. When meter U3 receives the message, it looks up its stored label (LC) and sends the message to unit LC.

The amount of processing which each meter has to perform in forwarding a message is not significantly affected by this technique, and the storage require-

ment for storing a single label is also not significant. This technique requires the message paths to the various different meters form a strict tree, but the optimal paths form a strict tree anyway. The processing burden on the meters is increased, but only to the extent of requiring each meter to be able to retain a single "return" address. This return address is updated every time an outward message passes through the meter, and has to remain valid only for the time required for the message to reach its final destination and return on its way back to the local controller.

If, after a message has been sent out, the topology of the system changes and a further message is sent out over a similar route before the first message has returned, this may result in the first message's return route being changed. This will not affect the operation of the system apart from slightly increasing the reliability of the return route.

Meter (and local controller) structure

Fig. 3 is a simplified block diagram of a typical meter 20 of the system. For simplicity, only the parts of the meter concerned with message transmission are shown; the meter will of course have further components (not shown) concerned with the usual metering functions, such as load measurement, charging calculations, load control based on tariff rates, etc.

The meter is coupled to the mains line 11 via a modem 21, which is coupled to a message memory 22 which comprises a command memory section 22A, a control subfield section 22B, a label sequence section 22C, and a data field section 22D. The control subfield section consists of three portions, a direction portion D, a label length portion L, and a pointer section P. (The data section may be continuous with the label sequence section, with the division between them being determined by the label length value.)

Any message which appears on the mains 11 is fed through the modem 21 into the message memory 22. Once the message is in the message memory, a control unit 23 selects, from the label sequence section 22C, the active label (which is pointed to by the pointer P in section 22B). The label so selected is compared with the label of the meter 20, stored in a meter label unit 24, by a label comparator 25.

If the active label in the message does not match the label of the meter, then the message is ignored, and may be erased. The meter awaits the next message, which will be written into the message memory (thereby erasing the present message if that has not already been erased).

If the active label matches the label of the meter, then the L and P portions of the control subfield in memory section 22B are compared by a target comparator 26, and the result passed to the control unit 23. If the two do not match, then the meter is not the target or intended recipient of the message. In this case, the pointer P in section 22B is extracted, incremented or decremented by 1, depending on the value of the direction D, by an arithmetic and logic unit 27, and returned to section 22B, and the message is then transmitted back onto the mains 11 via the modem 21.

If the target comparator 26 finds that the L and P portions of the control subfield in memory section 22B match, then the meter is the target or intended recipient of the message. In this case, the control unit 23 extracts the instruction from the command section 22A and performs the appropriate actions. This may typically involve copying the contents of the data section 22D into a memory 28, or copying some information from the memory 28 into the data section 22D, and possibly changing the contents of some further portion (not shown) of the message. In addition, the ALU 27 changes the value of the D section of the control subfield in memory section 22B from 0 to 1 and decrements the pointer P by 1. The control unit 23 then causes the message to be transmitted back onto the mains 11 via the modem 21.

If the system uses the modified form of message transmission system described above, then the message memory 22 will contain an additional section (not shown) for the "return" label, and the control subfield section 22B will be slightly simpler since it will not need to contain a pointer subfield.

The structure of the local controller LC is similar, as shown in Fig. 4, in that it has a modem 21', a message memory 22', and a main memory 28'. The local controller also includes control means 35 for constructing messages to be transmitted and for interpreting and processing messages received back from other units. Further, since the local controller is the ultimate source and destination of messages, it need not have any relaying capabilities.

Topology determination

In the system as described so far, it is necessary for the local controller to include a map (typically, in table form) of the topology the system. By using this map, it can construct messages, and their label sequences in particular, which will enable it to communicate with any meter.

In the system as described so far, however, the map has to be predetermined. In practice, the local controller must be able to monitor or explore the system, both to deal with changes in which units can communicate with which and to cope with the occasional addition of new meters and removal of existing meters.

For this, a message type SEARCH is used. This message type has the message format as discussed above, with the instruction SEARCH in the command field. The label sequence is as normal, except that the final label in the sequence is missing or absent (empty).

A SEARCH message is transmitted, just like any other message, along the path defined by the label field, until it reaches the end of the path. At this point, any meter which hears it finds that the label pointed to by the pointer is missing. If the meter detects this condition, it receives the message as well as merely hearing it. The label in register 24 is copied into the data memory section 22D and the message is transmitted as a return message (ie with the direction section of the control subfield in memory section 22B changed from 0 to 1 and the pointer P decremented by 1).

Instead of detecting that the label pointed to in the label sequence is missing, the meter can instead detect that the pointer value matches the length value in the control subfield in memory section 22B and that the instruction in the command memory section 22A is SEARCH. Similarly, the meter can insert its own label in the empty position in the label sequence instead of in the data field.

When the local controller sends out a SEARCH message, it will therefore in general receive a plurality of copies of the message in return, each with the label of a different meter. As noted above, suitable repetitions and conventional anti-collision measures can be taken to minimize the possibility and effects of interference between the return messages. The local controller can thus, by

sending out a SEARCH message to each meter in turn, determine the topology of the system. Further, once it has determined the topology of the system, it can maintain that topology up to date by sending out occasional SEARCH messages to confirm that topology.

For this, the local controller contains (Fig. 4) a topology table 36, consisting of a plurality of entries 37, one for each unit (including the local controller itself) in the system. Each entry has two columns, a first column 38 and a second column 39; the first column contains a single label, that for the meter associated with that entry, while the second column contains the labels of all meters with which that meter can communicate. (Unused portions of the memory are shown shaded.)

A topology control unit 40 is coupled to the control unit 35 and has two operating modes, initializing and maintenance. In the initializing mode, it causes the local controller to construct the topology table 36. For this, it inserts the local controller's label in the first column of the first entry in table 36 and causes the local controller first to send out a SEARCH message with a label list containing only the local controller's label. Each copy of that message which returns carries the label of a meter which the local controller can communicate directly with. These labels are written into the second column (39) of the entry in table 36 for the local controller.

When the entry for the local controller is complete, a new group of entries are constructed, one for each label in the second column of the entry just completed, with the labels from that column. Each of these entries is then processed in turn. For each, a SEARCH message is sent out with a label list containing the local controller label and its own (first column) label, and the labels of the meters which respond are entered in its second column. As each new label is entered in the second column, a check is made to see whether an entry already exists for that label; if not, a new entry for that label is added at the end of the table.

By continuing this process, a complete topological table for the system can be constructed. Each SEARCH message sent out goes through a chain of known meters (the length of the chain can be 0, ie consist of only the local controller), and discovers which meters can be reached from the end of that chain. The length of the chain gradually increases as the process proceeds, until the entire

network has been examined and there are no more meters to be discovered and the connections from all meters have been fully explored.

Obviously the topology can be stored in various other forms. Thus the table as described stores each link or hop twice, as each hop appears in the entries for both the two units connected by the hop, and it is possible to store the topology simply as a list of hops (in which case each hop would be listed only once).

Once the table 36 has been constructed, the topology control unit 40 changes to its maintenance mode. In this mode, it slowly cycles through the entries in the table 36, as a background processing task. The entries may be taken in a pseudo-random order, to minimize any imbalance of message loading in different parts of the network.

For each entry, a SEARCH message is sent out, and the existing entries compared with the labels returned in response to the SEARCH message. If one of the existing labels in column 2 is not returned, then it is deleted. If a new label appears, then it is entered in the second column and the table is checked to see whether there is already an entry for that label. If there is not, an entry for that new label is created and a SEARCH message is sent out for that new label to complete that entry. For each change apart from the appearance of a new label, an updating of another entry will also be required.

When the control unit 35 wants to send out another kind of message to a meter, it uses the topology table 36 to determine a path to that meter, eg by starting with the entry for that unit and backtracking up the table from second column values to first column values until the first entry (for the local controller itself) is reached. The sequence of labels so obtained is entered in memory 22C' as the label sequence for the message.

Message transmission is never perfectly reliable, as there are many possible sources of interference. So if there is no response to a message, the local controller will automatically resend it after a suitable interval.

However, it may happen that the control unit 35 finds difficulty in communicating with a meter; it may get no response after several resends, or it may have to resend for most messages to that meter. In that case, the topology table

36 can be used to try to find an alternative route to the meter. (If the route optimization system described in the next section is being used, the hop reliability information can be used to try to find reasonably promising alternative routes.)

It is also useful, for dealing with meters which become difficult to reach, to have a variant of the basic SEARCH message type, SEARCH-X. The SEARCH-X message asks for the meter X to identify itself by returning an acknowledgement if it receives a SEARCH-X message. Depending on the details of the topology unit, the control unit may have to send out the SEARCH-X message over all known routes, or it may be able to identify meters which are reasonably likely to be able to reach meter X and send the message only to those meters (or to those meters first).

If a meter disappears, ie cannot be reached at all by any other meter, then its entry obviously has to be deleted, and the entries for the other meters which used to be able to reach that meter also have to be updated to reflect the loss of that meter.

It may however be desirable to retain the entry for the lost meter in an archive store (not shown) for some reasonable period of time. If the meter is only temporarily inaccessible, eg through a temporary fault in that meter or in some part of the mains system feeding that meter, then when the meter reappears its entry can be recovered from the archive store. This effectively restores the topology table 36 to the state which is was in before the meter became inaccessible. If, as is likely, the system has not changed significantly apart from the occurrence and then correction of the fault making the relevant meter temporarily inaccessible, then this restored topology will be close to, if not identical to, the actual current topology of the system. The system can thus operate immediately on the restored topology. Any minor changes are unlikely to affect the operation of the system significantly, and these can be identified and the topology table updated to match the true current topology of the system during background mode topology maintenance.

The local controller can also send out SEARCH messages to meters close to the disappeared meter, in case it has been replaced by a new meter.

If there is a fault in the mains system which results in a group of meters becoming temporarily inaccessible, then this archive storage technique automatically stores the routing information for all the meters which have temporarily become inaccessible. The topology unit can be arranged to detect such a system fault, and to restore the routing information for all affected meters when the fault is cured, ie when communication is re-established with the first few of the lost meters.

If a meter disappears, ie is unreachable by the local controller despite repeated attempts to reach it using all previously known final hops to it, the local controller can signal that the meter is probably faulty. If several meters disappear at the same time, the local controller can signal instead that there is probably a fault on the mains distribution system.

The local controller can also send out a stream of messages to allow a part of the system to be traced. It may be desirable to use a special message type, say TRACE, for this purpose. A service engineer would then be able to monitor parts of the mains system for those messages. The service engineer may be provided with a monitoring device which acts as a unit of the system, receiving the TRACE messages. This will allow the engineer to communicate with the local controller.

Route optimization

The topology unit, as so far described, does two things. First, it establishes the topology of the system, in the sense of determining which units can communicate with each other (with a reasonable chance of success); and second, it can determine a route for the local controller to communicate with any other unit. However, this route determination may not be optimal.

To achieve optimal route determination, two more things are required: some form of hop quality evaluation, and some algorithm for determining an optimal route based on the hop qualities.

Considering the algorithm first, there is a well-known algorithm due to Dijkstra for determining the shortest route through a network where the lengths of the connections between the nodes are given. Basically, the algorithm determines the optimal paths through the network in order of increasing length. At

any intermediate point in the algorithm, the shortest paths to a number of nodes are known. The algorithm then determines the path lengths through each of these nodes to all adjacent nodes not yet in the shortest path listing, picks the shortest one, and adds that path and node to the list of shortest paths. The process is repeated until all nodes have been dealt with. This algorithm is efficient, and as it is a polynomial time algorithm, it can cope with systems of effectively unlimited size.

To apply this algorithm, a suitable measure of hop or path "length" or cost must be used. It is convenient to take this as inversely related to the hop quality. If, for example, the length or cost of the hop is taken as the logarithm of the reciprocal of the hop quality, then the shortest path is that with the highest probability of successful transmission.

One technique for measuring hop quality is for the receiving unit to measure the signal strength. The drawback of this is that it requires substantial elaboration of the receiving circuitry in every unit so that that circuitry can measure signal strength. Another technique is a type of marginal testing. A noise signal can be deliberately added to the mains system, to discover which hops fail as a result. This also has drawbacks; for example, it would require a network of noise signal generators at suitable points throughout the system, the message system would have to be expanded to turn them on and off, and there might be difficulties in turning them off reliably.

It is therefore preferred to measure the hop quality as the reliability of the hop, taken as the proportion of attempted transmissions over the hop which are successful. This requires nothing more than the monitoring of transmissions which are already occurring for other purposes.

This hop quality may be determined by the local controller. The local controller can determine directly the success rate of 1-stage transmissions to a meter, by counting the number of messages which is sends out to that meter and the number of those messages which are successfully returned. It can similarly determine the overall quality of a 2-stage path to a meter, and by dividing this by the quality of the first stage of that path, ie the first hop (which has been determined directly, as just described), it can determine the quality of the second stage of that path, ie the second hop. The qualities of the hops at the ends of 3-stage paths can similarly be determined, and so on for all hops.

This technique for determining hop qualities has a serious problem; it yields information only about those hops which are actually being used. (It is also slow.)

It is therefore preferred to use a different technique, which we can term passive distributed monitoring, for determining hop qualities. This requires each unit to include means for recording those units from which it hears messages.

Except for the occasions when a unit is actually sending a message, every unit is permanently listening for messages on the power supply network. Whenever a unit hears a message, it stores it and checks it to determine whether it is the intended recipient of that message. If the unit is not the intended recipient, then (as the system has been described so far) it ignores the message.

For passive distributed monitoring of hop quality, each unit records the source of every message it hears. That requires the unit to maintain a "heard messages" list, which is a list of all units from which it hears messages together with a count of the number of messages heard from each of those units.

In conjunction with this, the system has a further message type, REPORT-HEARD-LIST. The local controller can send this to any other unit in the usual way. When a meter receives a REPORT-HEARD-LIST command, it returns its heard message list.

The local controller can thus obtain the number of messages which a first meter has heard from a second meter. The local controller can also determine how many messages the meter has sent out. (The easiest way is for each meter to also keep a record, as part of its heard list, of the number of messages which it has itself sent out.) The local controller can therefore readily determine the reliability of the hop between those two meters.

When a meter reports its heard list, it must also clear that list. It is preferable for this to be performed in response to a further message type, CLEAR-HEARD-LIST, from the local controller, so that it is not cleared until the local controller has received the list. That avoids the possibility of the contents of the list being lost if the return REPORT message does not reach the local controller.

This passive distributed monitoring technique imposes extra loading on the meters. This loading does not affect the message transmissions, but requires extra processing and storage in the meters. The amount of extra processing required is relatively small, since a meter has to inspect every message it hears to determine whether it is the intended recipient of that message. The amount of extra storage required can be kept within reasonable bounds by limiting the size of the list, ie the number of meters which can be entered in the list; provided that the size of the list is reasonable, this will result only in excluding potential hops which either are highly unreliable or are from units which have have very low usage, ie send out very few messages.

Addresses, labels, and identifiers

The "labels" which we have referred to in the description of the Fig. 1 system have, up to this point, served merely to provide some general kind of addressing of the units, and could equally well have been termed addresses. It will often be convenient for the units to be given identifiers, eg during manufacture, which are globally unique, eg by concatenating a manufacturer's number (which distinguishes the manufacturer from all other manufacturers) and a serial number. Such identifiers can be used for addressing, ie as labels (in the sense used up to now).

However, such globally unique identifiers have the disadvantage that they tend to be fairly lengthy. Since the label list may contain several labels, this may limit the amount of traffic which the system can cope with.

The system is therefore preferably designed so that it can use labels which are distinct from the unit identifiers. Each meter is assigned a distinct label by the local controller, and these labels (rather than the identifiers) are used in the route field.

For this, when a meter receives a SEARCH message, it returns its label if it has one and its identifier (from an identifier register 29, Fig. 3, which will usually be hard wired or burnt in) if it does not have a label. When the local controller receives a SEARCH message return containing an identifier, it constructs a new entry in the topology table 36, entering the identifier in a third column 41, and selects a label for that meter and enters the label in the first column. It also immediately sends back a NAME message to that meter, including

the identifier and the new label; the meter copies the label into its label register 24.

The NAME message will, like the SEARCH message, have an empty final label in its label list. A meter receiving a NAME message with its active label empty will treat it somewhat like a SEARCH message; the meter will inspect the DATA field to see whether the identifier therein matches the identifier of the meter in register 29, and if it does, it will copy the label in the data field into its label register 24.

The use of distinct labels and identifiers allows the use of variants of the basic SEARCH message. The SEARCH message as so far described is in effect a SEARCH-ALL message, which is received and responded to by all meters hearing it. Two variants can also be used, a SEARCH-NEW message which only meters without labels will receive and respond to, and a SEARCH-OLD message which only meters with labels will receive and respond to.

Multiple controllers

Many mains systems are fed from only one switching and transformer station, which is the natural location for a local controller. Such systems will automatically have only one local controller. But as noted above, a large mains or grid system may have more than one local controller. This can happen as a result of changes in the LV (low voltage) mains system, eg to provide an additional supply to a heavily loaded part of the system served by a switching and transformer station, or as a result of message signal coupling through the IV (intermediate voltage) side of the switching and transformer stations. (It may well be desirable to couple the messages of the present system between the IV (eg 11 kV) and LV (240 V) sides of the grid system, eg to permit monitoring and control of switching and transformer stations, or to permit a single local controller to serve several LV mains systems which are geographically large but have relatively few meters on them.)

This presents a risk of "double control"; that is, of two local controllers both communicating with the same meter. This can result in the meter receiving conflicting information from the two local controllers, eg different tariff rates or times of change. Also, if both local controllers read the meter reading, this requires some form of higher level monitoring to avoid double charging. It is

therefore desirable for the system to minimize the risk of "double control". It is also desirable to have some means of rationalizing the division between the different local controllers.

There are two broad types of technique for dealing with this. One is for the local controllers to communicate with each other indirectly via the meters; the other is for there to be some higher level form of control and communication between the local controllers, either directly or via some higher authority such as area controllers.

One basic principle for resolving potential conflicts is for each controller to have a unique distinguisher, which is included as part (conveniently, the initial part) of all labels used by it. Each meter will therefore be associated with (owned by) a particular local controller, and will only respond to or relay messages from that local controller.

The local controller distinguishers can be their unique identifiers, but it is desirable for the distinguishers to be related to the identifiers in a similar way to that in which the meter labels are related to the unit identifiers.

If a meter already has a label, it can respond to any SEARCH message by returning that label, regardless of which local controller the SEARCH message has come from. The return SEARCH message will of course only return to the local controller which sent it out (the first local controller). (It will only be relayed by meters associated with that local controller; and if it happens to reach a second local controller, that local controller will ignore it because the local controller label in the label sequence of the message will not match that of the second local controller.) If the return SEARCH message contains a label including the distinguisher of a second local controller, the first local controller will ignore that meter.

This principle may be modified by including a hop count (or distance) register 30 in each meter. When a local controller finds a meter without a label, it will send a NAME message to it containing not only a label (including the local controller distinguisher) but the hop count from the local controller to the meter, and the meter will store this hop count in its H register 30. If the meter subsequently receives a SEARCH message, it will respond by returning its hop count along with its label.

If a second local controller sends out a SEARCH message and receives a return message including a label associated with the first local controller, it will also receive the hop count for the distance between the meter and the first local controller. If that distance is substantially greater than the meter's distance from the second local controller, the second local controller can send back a RENAME message which renames the meter with a label associated with the second local controller. (The RENAME message will also require the meter to send back its identifier, so that the second local controller can maintain its topology table.)

In due course, the first local controller will find that the meter has disappeared from its topology table, and will therefore update that table accordingly. It may find the meter responding to SEARCH message (as an apparently new meter), but it will find that the meter's distance from it is greater than the meter's distance from the second local controller, so it will therefore not attempt to recapture the meter for itself.

The distribution of meters among several local controllers will therefore gradually become rationalized. The value of the hop count difference at which one local controller is allowed to capture a meter from another local controller sets the balance between instability on the one hand and possible persistent imbalance between the regions of control the different local controllers on the other.

It is of course desirable for hop counts of the meters to be maintained ar updated by the background topology maintenance processes of the local controllers which control the meters.

In the system as so far described, if a meter is owned by one local controller, it may hear messages from another local controller but will ignore them (unless they are SEARCH messages, as just discussed). It may be desirable to modify the meters so that a meter which hears a message from another local controller records that fact (together with the identity of that local controller). When the meter receives a message from its own local controller, it can set an indicator in the return version of the message to indicate that it has heard a message from another local controller (or include the identity of that other local controller). This information can then be used by the local controllers concerned to change the ownership of the meter if desired.

Instead of this local adjustment of the division of the meters between local controllers, it may be preferable for meters which can be reached by more than one local controller to be assigned to one or other local controller by some higher level procedure, eg an area controller to which several local controllers report.

A meter will normally contain a clock, which is free-running but is checked at suitable intervals against synchronizing signals included in messages sent its local controller. The meter may therefore be arranged to monitor the time elapsed since it last received a message (of any kind) from its local controller (the primary local controller). It is convenient for a meter to include this elapsed time in its response to a SEARCH message from any other local controller (the secondary local controller). This will allow the secondary local controller to discover meters which have lost communication with their primary local controllers.

The secondary local controller can then take appropriate action. This may involve taking control of the meter. It may also involve exploring the network in the region of that meter more intensively. If the secondary local controller finds more meters which have lost communication with their primary local controllers, it can take control of them and/or report to a higher authority that there appears to be a problem with the primary local controller or its area.

The local controllers will also gradually build up information regarding their neighbouring local controllers. This may be reported to and used by a higher level system (eg area controllers, each of which controls a number of local controllers).

If there is a large number of meters which are on the border between two different local controllers, there may be substantial conflict between messages from the two local controllers, resulting in loss of messages. In such circumstances, an area controller can be arranged to assign different time slots to the two local controllers, perhaps with the widths of the slots being proportional to the numbers of meters which each local controller owns, to reduce this problem.

Further, if a local controller should become faulty, an area controller can be arranged to provide one or more adjacent local controllers with the identification codes (eg MACs - message authentication codes) of the faulty local controller.

Those adjacent local controllers can then communicate with those meters without having to change the ownership of the meters. When the failed local controller resumes operation, it will not have to re-establish ownership of its meters; all that will be necessary is for its identification codes to be withdrawn from the other local controllers.

Link boxes

Although, as noted above, most LV mains systems are fed from only one switching and transformer station, it is possible for a part of an LV mains system to be fed from more than one such station, as also noted above. Tl. can happen as a result of a permanent connection. It is more usual, however, for the mains systems fed by the different switching and transformer stations to be coupled via link boxes. The mains systems fed by the different switching and transformer stations are therefore normally separate.

However, if the load on a particular part of a mains system is too great for its switching and transformer station to handle, the supply to that part of the mains system can be supplemented from a neighbouring switching and transformer station via a link box. Similarly, if one switching and transformer station should suffer a fault, its mains system can temporarily be supplied from one or more neighbouring switching and transformer stations via link boxes.

The messages of the present signalling system will generally pass through conventional link box. This will result in potential conflicts between adjacent local controllers, which can be resolved as discussed above. However, it is preferred to modify the link boxes by including a low pass filter in the mains circuit and a special type of unit, a link unit, which is coupled to all the mains systems connected to the link box. (A link box may connect more than two mains systems.)

The low pass mains filter prevents the messages of the present system from passing directly through the link box. Such a filter can readily be formed by a suitable inductance and capacitance. Since the signal frequencies are some 3 orders of magnitude above the mains frequency, excellent blocking of signals can easily be achieved with no significant effect on the mains supply.

The main characteristic of the link unit is that it acts as a repeater; it repeats a signal received on any of the mains systems connected to the link box onto all the other mains systems. Each local controller can therefore reach the mains systems of adjacent switching and transformer stations. However, the message route to an adjacent mains system has to include the link unit. Link units are recognized as such by local controllers, eg by being given distinctive labels or addresses. Each local controller therefore knows when it is reaching through a link unit.

A link unit can be arranged to repeat only between those mains systems which the link box is coupling together, or to repeat automatically onto all mains systems which its link box is connected to. In the latter case, it can be arranged to inform the local controllers of the current state of the link box (in response to messages of suitable type from the local controllers). The local controllers can the take appropriate action, eg their topology units can update their topology lists.

The link unit can also be arranged to monitor the conditions of the mains systems, eg their voltages and the currents through the link box, for reporting to the local controllers. The link unit can also be coupled to link box control circuitry, so that the link box can be controlled from the local controllers, eg to turn a link on if the load on part of one mains system is so great that the voltage at the link box falls below a preset level.

Transfers of meters between different local controllers are at best likely to increase the costs incurred by the electricity supply company. They can cause very serious difficulties to other organizations whose signals are carried by the present system, eg other utility systems (gas, water, etc) and other signalling systems, eg for alarm systems. It is therefore desirable to minimize such transfers. This can be achieved relatively easily if different local controllers are separated by link boxes and link units.

Claims

1 A remote mains meter control system comprising a mains system (10-14), a central station (LC), and a plurality of meters (U1-U11) communicating with the central station by means of messages passed over the mains system, *characterized in that* substantially all of the meters (Fig. 3) act also as message forwarding (relay) units.

2 A remote mains meter control system according to claim 1, *characterized ... that* the central station includes, in each message, a list (label list) (eg LC-U3-U7) of all meters (U3) which are to forward the message on its route to the final destination meter (U7).

3 A remote mains meter control system according to claim 2, *characterized in that* each meter deletes its label from label list on the return journey (I) of the message to the central station.

4 A remote mains meter control system according to claim 2, *characterized in that* each meter, on the outward journey (O) of the message to the final destination meter, deletes the label of the preceding label from the label list and stores that label, and, on the return journey of the message to the central station, adds the stored label to the message as its immediate next destination unit.

5 A remote mains meter control system according to any previous claim, *characterized in that* to determine the topology of the system, the central station sends out enquiry (SEARCH) messages which request meters hearing them to respond with their identifications.

6 A remote mains meter control system according to claim 5, *characterized in that* the central station includes a topology table (36, Fig. 4) for storing the pairs of meters which can hear each other.

7 A remote mains meter control system according to claim 6, *characterized in that* when the central station finds that a meter or group of meters is no longer accessible, it transfers the respective entries from the topology table to an archive store.

8 A remote mains meter control system according to any of claims 5 to 7, *characterized in that* the central station sends out enquiry (SEARCH) messages at a high rate on detecting a substantial change of topology, and at a low rate as a background activity at other times.

9 A remote mains meter control system according to any of claims 5 to 8, *characterized in that* the central station can send out a modified enquiry message (SEARCH-X) which identifies a particular meter and is responded to only by that meter.

10 A remote mains meter control system according to any of claims 5 to 9, *characterized in that* each meter has a unique identifier and has a label register (24, Fig. 3) into which a label can be written in response to a message from the central station, the meter responding to an enquiry message with its unique identifier if its label store is empty and with its label if its label store contains a label.

11 A remote mains meter control system according to claim 10, *characterized in that* the central station can send out enquiry (SEARCH) messages which ask for identification from any meter or from meters only with or only without labels.

12 A remote mains meter control system according to either of claims 10 and 11, *characterized in that* the central station can include an identification of itself in the labels which it assigns to meters.

13 A remote mains meter control system according to claim 12, *characterized in that* each meter has a distance (hop count) register into which a distance can be written in response to a message from the central station, the meter including the hop count in its response enquiry messages.

14 A remote mains meter control system according to any of claims 5 to 13, *characterized in that* each meter maintains a list (HEARD LIST) of meters from which it hears messages, and the central station can send a message (REPORT-HEARD-LIST) requesting the transmission of that list.

15 A remote mains meter control system according to claim 14, *characterized in that* the central station can send a message (CLEAR-HEARD-LIST) clearing the list from a meter.

16 A remote mains meter control system according to any of claims 5 to 15, *characterized in that* each meter includes a time clock circuit and can include its time count in messages returned to the central station.

17 A remote mains meter control system according to any of claims 5 to 15, *characterized in that* the mains system includes at least one link box which couples two or more parts of the system together, the link box including filter means for preventing the passage of signals therethrough and a link unit which controllably couples signals between the different parts of the system coupled by the link box.

18 A remote mains meter control system substantially as herein described with reference to the drawings.

19 Any novel and inventive feature or combination of features specifically disclosed herein within the meaning of Article 4H of the International Convention (Paris Convention).

HELLER IKKE ET DÅRLIGT KRAV!

YES !

Fig. 1

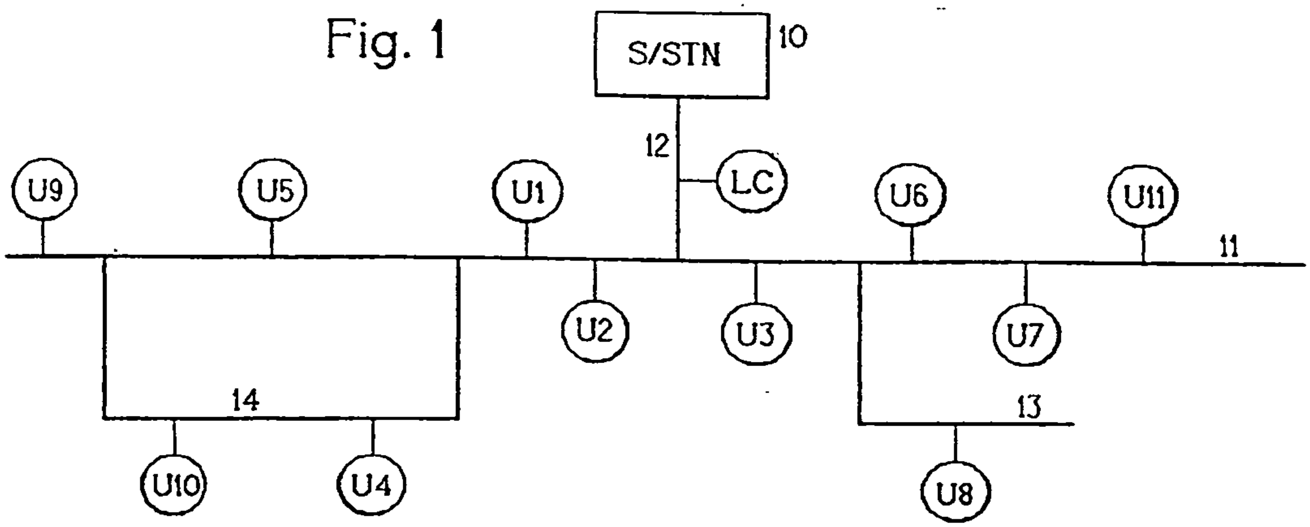
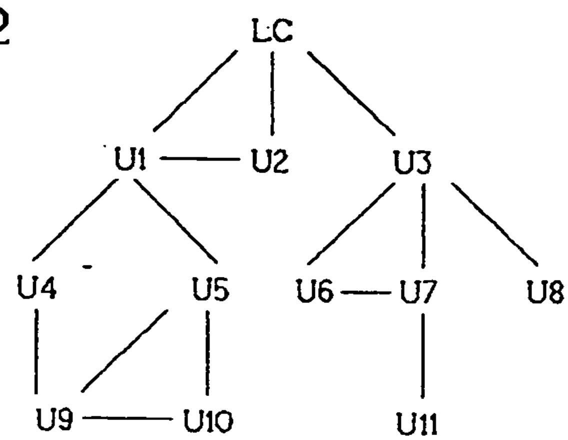
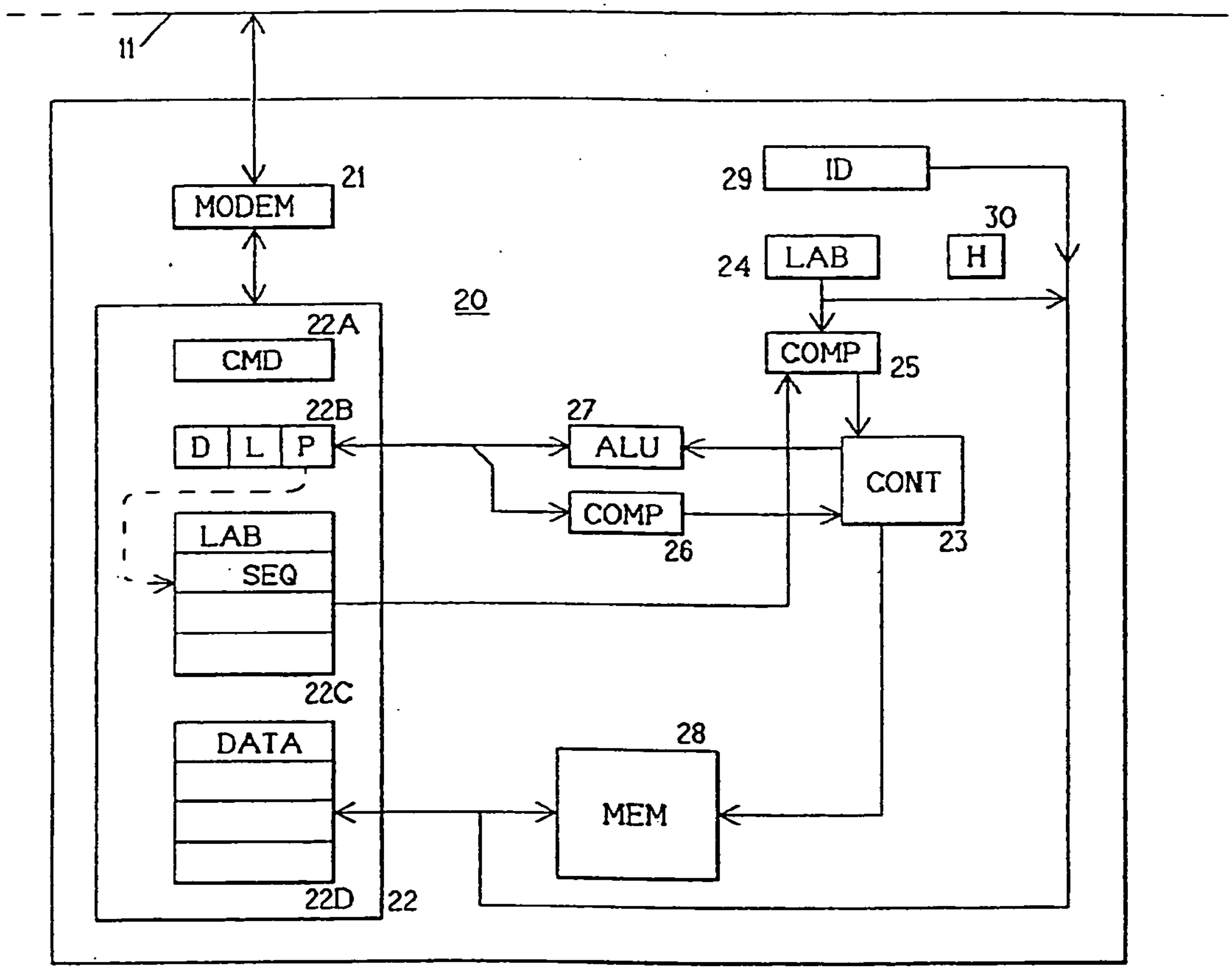

S/STN
10
12
LC
U9
U5
U1
U6
U11
11
U2
U3
U7
14
13
U10
U4
U8

Fig. 2


LC
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11

2/3

Fig. 3


11
MODEM
21
29
ID
30
24
LAB
H
20
22A
CMD
COMP
25
22B
27
D
L
P
ALU
CONT
COMP
LAB
26
23
SEQ
22C
28
DATA
MEM
22D
22

3/3

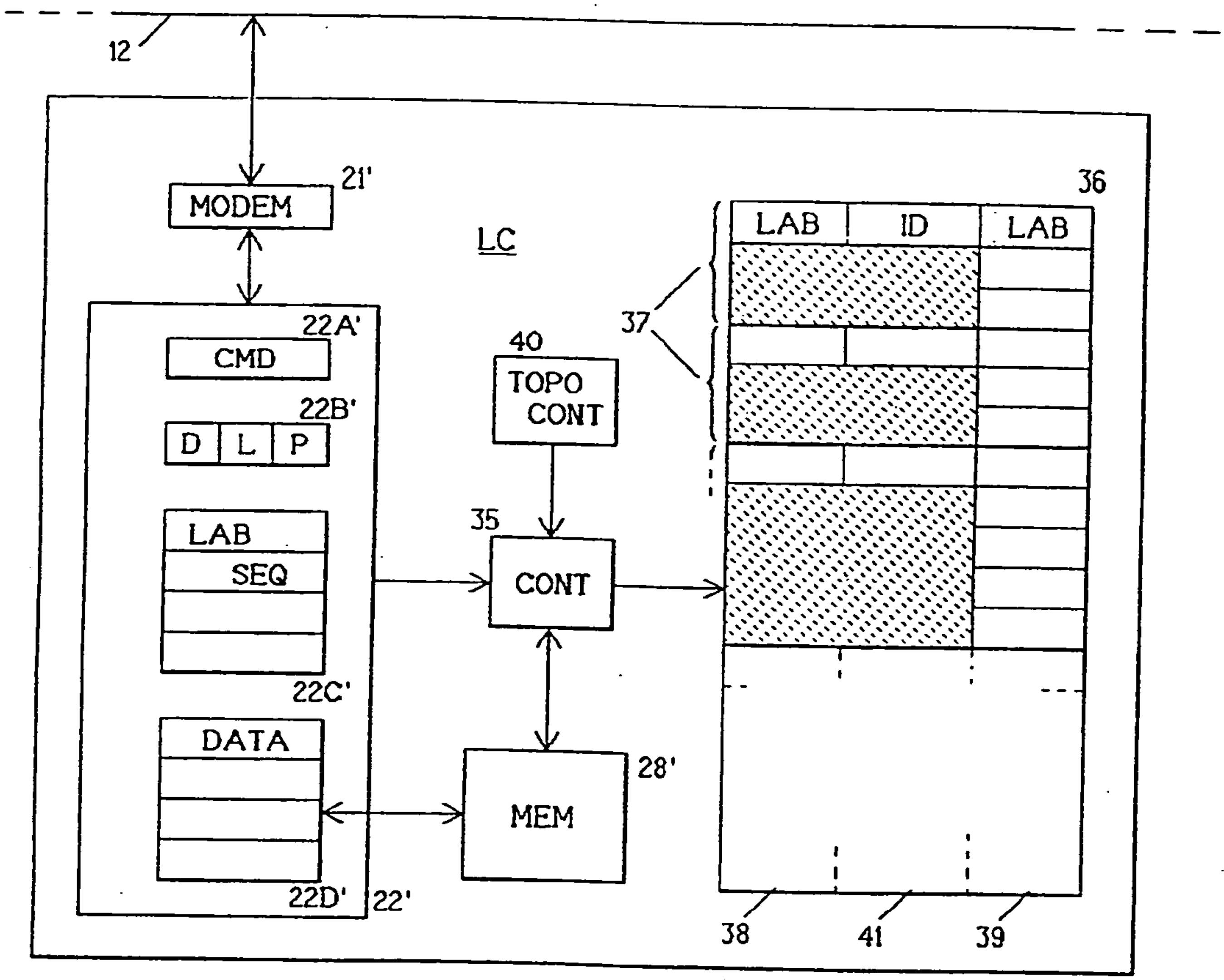

12
MODEM
21'
LC
36
LAB
ID
LAB
37
22A'
CMD
40
TOPO
CONT
22B'
D
L
P
LAB
SEQ
35
CONT
22C'
DATA
28'
MEM
22D'
22'
38
41
39

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB 94/01391

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H04L12/56 H04Q9/00 H04B3/54

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 395 495 (SCHLUMBERGER) 21 December 1988 see abstract see page 4, line 50 - page 6, line 6 see page 6, line 23 - line 52 see page 8, line 34 - line 36 see page 10, line 57 - page 11, line 11 see page 14, line 5 - line 7	1,2,5-7, 9
Y		3
A		8,11,13, 16,17

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
19 October 1994	16. 11. 94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Mikkelsen, C

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 388 672 (ASEA BROWN BOVERI) 26 September 1990 see abstract see column 1, line 41 - column 2, line 28 see column 4, line 8 - line 14 see column 4, line 53 - line 58 see column 5, line 49 - line 58	1,5,6, 8-11,14
A		2,6,12, 15

X	EP,A,0 201 253 (EMI) 12 November 1986 cited in the application see abstract see page 4, line 8 - line 30 see page 6, line 1 - line 3 see abstract	1
A		2-6,9,12

Y	WO,A,92 05648 (ERICSSON) 2 April 1992 see abstract see page 3, line 22 - page 4, line 12	3
A		4

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB 94/01391

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		CA-A- 2015492	27-10-90
		JP-A- 3064132	19-03-91
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		DE-D- 59006869	29-09-94
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